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Our File 16072
International Patent Application No. PCT/CH2003/000243
Delta Energy Systems (Switzerland) AG,
Written Opinion of 3 February 2004

Dear Sirs,

1 New claims 22-31

In response to the Written Opinion of 3 February 2004 with respect to the international patent application in caption and your confirmation of the extension of the time limit of 10 May 2004 please find enclosed new claims 22-31 (replacement sheets 15-16). The international preliminary examination report shall be established on the basis of these new claims.

The following amendments have been made:

- In claim 26, the term "means for applying a first ... voltage" has been replaced by the term "an injection voltage source for applying a first ... voltage ";
- in claim 27, the term "the means for applying" has been replaced by the term "the injection voltage source for applying";
- in claim 30, the term "the means for applying" has been replaced by the term "the injection voltage source for applying";
- in claim 31, the term "the means for applying a first" has been replaced by the term "the injection voltage source for applying a first".

The remaining claims are not amended.

2 Short comment on the cited references

2.1 D1: A three-phase soft-switched ...; De Doncker et al.

Reference D1 deals with soft-switched high power density DC/DC converters. Fig. 1 shows a pseudo resonant full bridge DC/DC converter which includes a voltage source (VCC) with a center tap where the center tap is used to connect the capacitive snubbers (C1, C2) to ground (fig. 1, first paragraph on page 797). Inductors (L1, L2) are shown in parallel to the snubber capacitors (C1, C2) where these inductors (L1, L2) are described to be leakage inductances of the power transformer Lm (first paragraph on page 797).

2.2 D2: EP 0 430 242 A2; Systel Development & Industries Ltd.

Reference Systel discloses a protective circuit (fig. 2) for a diode (D1) in series with a switching device (S1). The protective circuit includes a transformer (T1) with an excitation winding (Ne) in series with the diode and a sink winding (Ns). The excitation winding senses the recovery current through the diode immediately after operation of the switching device and a reverse current is induced in the sink winding (col. 3, line 30 ff.). In series with the sink winding, a switch (S2) is provided and both are coupled parallel to the diode (D1). Since at least a part of the reverse current through the sink winding is directed back to the voltage source, the power loss can be reduced. This principle is explained with reference to fig. 2. However, according to the description, this principle is also applied in the arrangements according to the other figures.

3 Patentability

3.1 Core of the invention

It is a goal of the invention to reduce or eliminate the reverse recovery losses in the output rectifiers of a power supply with a power transformer. This goal is achieved by injecting a properly phased AC voltage into the secondary winding (for example via the primary winding) of the power transformer. This supplemental bias voltage steers the current flow in the output rectifiers such that the current through the output rectifiers is negligible or zero when the voltage polarity in the secondary winding changes due to the voltage change across the primary winding.

3.2 Novelty

Regarding D1, it is to note that the inductor L1 which the examiner interprets as an injection voltage source is nothing else than the leakage inductance of the transformer Lm. As the name implies and as described in the first paragraph on page 797 of reference D1, the leakage inductance increases the energy losses. The leakage inductance L1 may therefore surely not serve for injecting a voltage in a transformer winding in order to shape the current through the output rectifiers with the goal of reducing the reverse recovery losses in the output rectifiers. D1 does therefore not disclose an injection voltage source connected to the primary winding.

Regarding D2, it is agreed with the examiner that D2 shows an arrangement to reduce the power losses due to reverse recovery. However, in D2 this goal is achieved by different means. In D2, the losses are reduced by lowering the reverse current through the diode at the moment when the reverse current is flowing through the diode, that is during the period when a negative voltage is applied across the diode. This is done by redirecting a part of the reverse current back to the voltage source. In the invention, a properly phased alternating bias voltage is injected into

a winding of the power transformer such that the current through the rectifiers is forced to cease before the voltage across the rectifier changes its polarity. That is, the reverse current has already ceased to exist when the negative voltage is applied across the rectifiers.

That is, none of the cited references teaches the essential features of the invention, namely an injection voltage source connected to the primary winding or an injection voltage source for applying a reverse bias voltage to the diode in order to terminate forward conduction in the diode and to deplete the carriers in the diode before the voltage across the switch is reversed. Hence, the claims are new.

3.3 Inventive step

As outlined above, it was not known in the art to provide an injection voltage source in a power conversion circuit or in a method of power conversion as claimed in claims 1, 5, 26 and 32 respectively. It therefore can not be obvious for a person skilled in the art to incorporate this features into a power conversion circuit or a corresponding power conversion method.

Hence, the independent claims 1, 5, 26 and 32 are patentable because they are new and involve an inventive step. Since each other claim depends on one of the independent claims, the dependent claims are patentable too.

4 Examination report

As the (partially amended) set of claims overcomes all of the objections of the Written Opinion a positive international preliminary examination report can be expected.

In the case the examiner requires further clarifications or does not agree with the above comments he is kindly asked for a call-back.

The representative:

Werner A. Roshardt, Patent Attorney

- Replacement sheets 15-16
- Form of acknowledgement of receipt

22. The power conversion circuit according to claim 21, wherein the four electrically controlled unidirectional semiconductor switches are electrically controlled to provide current in a first direction through the at least one primary winding, a short across the at least one primary winding and the injection voltage source, current in a reverse direction through the at least one primary winding, and then again a short across the primary winding and the injection voltage source, whereby the first and second secondary windings produce voltages of opposite polarities with intervening periods of a substantially lower voltage induced therein by the injection voltage.

23. The power conversion circuit according to claim 22, wherein the at least one primary winding of the power transformer is connected at one end to a junction of a pair of the electrically controlled switches, and in series with the injection voltage source, the injection voltage source being connected to a junction of a further pair of the electronically controlled switches, the at least one primary winding and injection voltage source delivering current substantially triangular in its plot of current versus time to the junctions of the pairs of electrically controlled switches to assure substantially zero voltage switching thereby.

24. The power conversion circuit according to claim 23, the injection voltage source producing substantially an AC square wave voltage.

25. The power conversion circuit according to claim 24, wherein the injection voltage source comprises an auxiliary transformer having a primary connected in series with the at least one primary of the power transformer and having a secondary connected to a capacitor connected to ground.

26. A power conversion circuit having a power transformer with a primary winding and at least one secondary winding, an input circuit connected to the primary winding, an output circuit connected with the at least one secondary winding and having a semiconductor rectifying means coupled in current conducting relation with the at least one secondary winding, an inductor coupled in current conducting relation between the semiconductor rectifying means and an output load connection; the improvement comprising:

an injection voltage source for applying a first, relatively low reverse bias voltage to the semiconductor rectifying means to halt forward conduction and deplete carriers in the semiconductor rectifying means prior to each application to the semiconductor rectifying means of a reverse bias larger than the first, relatively low reverse bias voltage.

27. The power conversion circuit according to claim 26, wherein the injection voltage source for applying a reverse bias voltage comprises means for injecting a supplemental voltage on the primary winding of the power transformer in addition to a main excitation voltage applied by the input circuit to the primary winding.

28. The power conversion circuit according to claim 27, wherein the means for injecting a supplemental voltage comprises an auxiliary transformer connected with the primary winding of the power transformer to apply a supplemental voltage that is an alternating voltage producing in the at least one secondary winding of the power transformer the first, relatively low reverse bias voltage.

29. The power conversion circuit according to claim 28, wherein the semiconductor rectifying means comprises first and second semiconductor rectifying devices connected with first and second secondary windings of the power transformer, the auxiliary transformer applies an alternating voltage of first and second primary voltage levels to produce in the first and secondary windings first and second secondary voltage levels reverse biasing the first and second rectifying devices, respectively.

30. The power conversion circuit according to claim 26, wherein the semiconductor rectifying means comprises a pair of semiconductor unidirectional current conducting devices, and the injection voltage source for applying a reverse bias voltage alternately reverse biasing the semiconductor unidirectional current conducting devices and driving carriers from that device into the other, conducting unidirectional current conducting device.

31. The power conversion circuit according to claim 30, wherein the injection voltage source for applying a first, relatively low reverse bias voltage comprises means for applying an alternating voltage to the primary winding of the power transformer, wherein the input circuit comprises a plurality of semiconductor switching means, connected with the power transformer primary winding and the means for applying an alternating voltage, the means for applying an alternating voltage being connected into the primary circuit to inject alternating current into the semiconductor switching means to assure substantially zero voltage switching thereof.